Surface metallic pattern for enhancement of a THz field in a two-dimensional electron plasma

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Nonlinear effects at THz frequencies have been mainly studied with powerful sources (synchrotrons, free electron lasers, pulsed molecular lasers) or with time-domain spectroscopy systems based on high-power fs lasers. Another approach is based on using relatively weak sources and a resonant enhancement of the amplitude of the electromagnetic field in a resonator. Taking into accounrt the frequency of the THz band (spanning the range between 0.1 THz and 10 THz), one has to look for resonant cavities which could operate at these extremly high frequencies.

Such cavities are offered by micrometer size metallic patterns which shape is typically that of a split-ring resonator (SRR) or a planar antenna (PA). A reaction of such elements to the electromagnetic radiation can be found only numerically by solution of the Maxwell equations in the time and space domains. A numerical tool adopted is either a finite element (FE) method or a finite difference time domain (FDTD) method.

The aim of the present work was to verify a possibility to obtain a high enhancement factor for the amplitude of THz fields in the case of a SRR and a bow-tie PA processed on a GaAs/AlGaAs heterostructure with a two-dimensional electron plasma positioned at 100 nm below the wafer surface. A general idea behind this study is to resonantly increase a ponderomotive potential in real structures (to be processed in the nearest future) placed at a high magnetic field and to observe its influence on the dynamics of magnetoplasmons.

In the case of the SRR, we considered a rectangle (26 μm x 42 μm) formed by a 3,5 μm-wide Au path with a capacitive element in the rectangle interior, and we changed the distance between the resonators between 2 μm and 20 μm. In the case of the bow-tie PA, we changed the distance between the apexes of the PA between 2 μm and 4 μm and the bow-tie angle. In each case, a distribution of the electromagnetic field was determined with a FDTD method (the Meep package) at the position of the plasma layer, with taking into account a linear polarization of radiation (parallel to both edges of the SRR rectangle or to the longitudinal axis of the PA) and the phase of the wave oscillations. In calculations, the frequency of radiation was varied between 0.1 THz and 5 THz which corresponds to the frequency band covered with THz sources available in our laboratory.

The calculations revealed excitation of rather broad resonances (the width is typically of the order of 0.5 THz) and "hot spots" within the pattern where the enhancement of the amplitud of the THz electric field is at the level of 10^3. The existence of such hot spots is particularly interesting from the point of view of an optically detected resonance microluminescence system developed in our laboratory with which one could experimentally determine the value of the enhancement factor by observation of the influece of an enhanced THz field on spectra and dynamics of excitons.

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